10

Soil and Sediment Monitoring

Gretchen M. Gallegos
Erich R. Brandstetter
Donald H. MacQueen

Introduction

Soil is weathered material, mainly composed of disintegrated rock and organic material, which will sustain growing plants. Soil can contain pollutants originally released directly to the ground, to the air, or through liquid effluents. Department of Energy (DOE) guidance for environmental monitoring states that soil should be sampled to determine if there is measurable long-term buildup of radionuclides in the terrestrial environment and to estimate environmental radionuclide inventories (U.S. Department of Energy 1991). The guidance recommends that radionuclides specific to a particular operation or facility as well as those that occur naturally should be monitored. Particulate radionuclides are of major interest in the LLNL soil monitoring program because airborne particulate releases are the most likely pathway for LLNL-induced soil contamination.

Sediments are defined, for the purposes of this chapter, as finely divided solid materials that have settled out of a liquid stream or standing water. The accumulation of radioactive materials in sediment could lead to exposure of humans through ingestion of aquatic species, through sediment resuspension into drinking water supplies, or as an external radiation source (U.S. Department of Energy 1991). However, the LLNL Livermore site and Site 300 do not have habitats for aquatic species that are consumed by people, nor do they have surface drainage that directly feeds drinking water supplies.

Soil monitoring in the arroyos is also targeted in the Ground Water Protection Management Program (GWPMP) because recharge of natural runoff through the stream beds of arroyos is a significant source of resupply to the Livermore Valley ground water basin (Webster-Scholten 1994). Infiltrating rainwater may carry with it any dissolved constituents that may be present.

In 1998, soil samples from Big Trees Park in Livermore were analyzed to better determine the extent and origin of plutonium present. Previous sampling at the park in 1995 and 1993 had detected plutonium at concentrations above fallout background.

10 Soil and Sediment Monitoring

Surface Soils and Sediments

Since 1971, surface soil sampling in the vicinity of the LLNL Livermore site and Site 300 has been part of a continuing LLNL monitoring program designed to measure any changes in environmental levels of radioactivity and to evaluate any increase in radioactivity that might have resulted from LLNL operations. These samples have been analyzed for plutonium and gamma-emitting radionuclides, such as depleted uranium, which is used in some explosive tests at Site 300. The inclusion of other gamma-emitting naturally occurring nuclides (^{40}K and ^{232}Th) and the long-lived fission product ^{137}Cs provides background information and baseline data on global fallout from historical aboveground nuclear weapons testing. In addition, LLNL analyzes Site 300 soils for beryllium because it is a potentially toxic metal used at this site.

Similarly, sediment samples have been collected from selected arroyos and other drainage areas at and around the Livermore site since 1988; these locations largely coincide with selected storm water sampling locations (see Chapter 7). The number of sediment sampling locations was reduced in 1994 to correspond to reductions in storm water sampling locations. In addition, in 1991, LLNL began analyzing surface soil samples for beryllium, a potentially toxic metal used at both the Livermore site and Site 300. However, analysis for beryllium was discontinued at the Livermore site in 1995 because beryllium was not ever measured above background values.

Location maps for soil and sediment sampling conducted during 1998 are provided in **Figures 10-1** through **10-3**. The locations were selected to represent background concentrations (distant locations unlikely to be affected by LLNL operations) as well as areas where there is the potential to be affected by LLNL operations. Areas with known contaminants, such as the Livermore Water Reclamation Plant (LWRP), are also sampled. In general, Site 300 soil sampling locations were established around firing tables and other areas of potential soil contamination. The PRIM location was added to the sampling program to correspond with air sampling conducted at that location. The PRIM site is downwind of Site 300 and sufficiently close to the Site 300 boundary to potentially be affected by Site 300 operations. Approximately 10% of samples are collected in duplicate; two identical samples are collected at each location chosen for this sampling. All soil and sediment sampling locations have permanent location markers for reference.

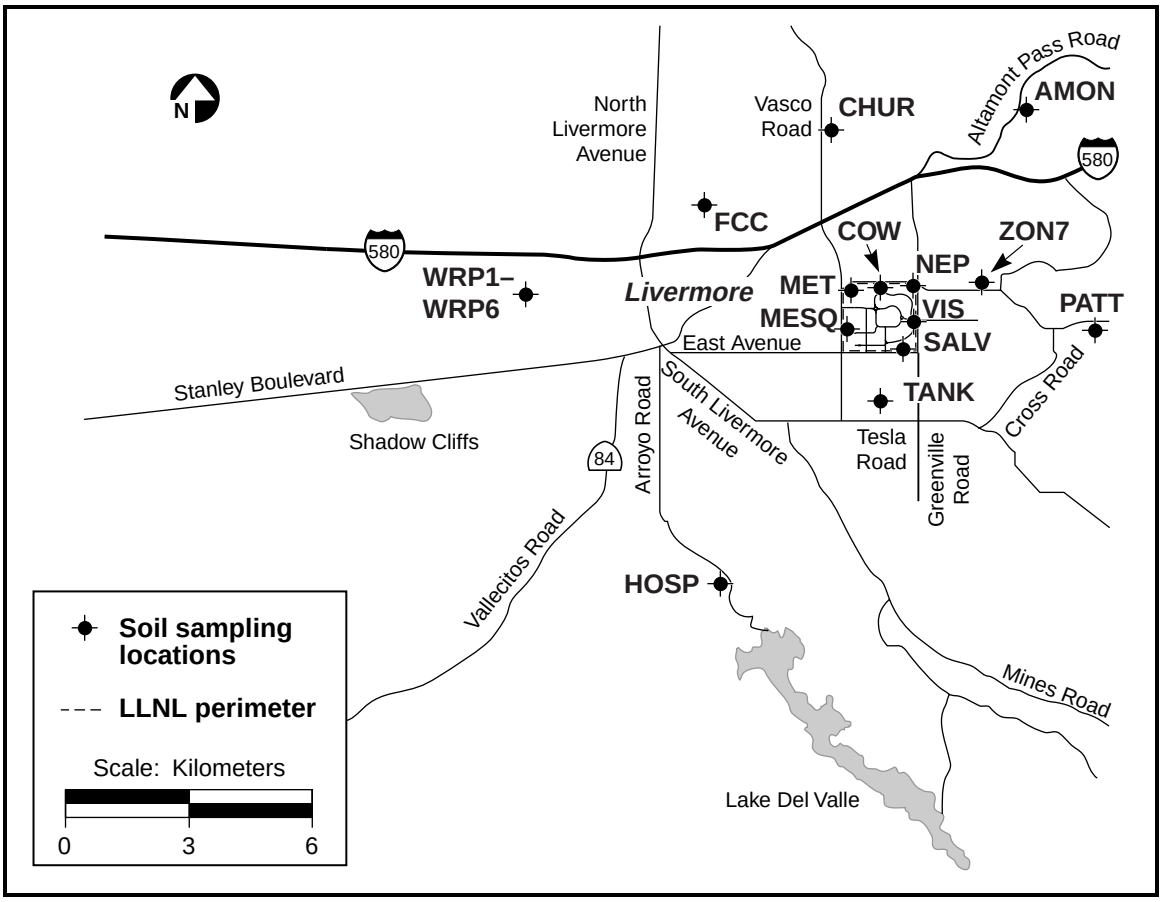

Figure 10-1. Soil sampling locations, Livermore Valley, 1998.

Methods

Soil and sediment sampling is conducted according to written, standardized procedures (Tate et al. 1995). Soil samples are collected from undisturbed areas near permanent location markers. These areas generally are level, free of rocks, and unsheltered by trees or buildings. All samples are collected from the top 5 cm of soil because aerial deposition is the primary pathway for potential contamination and resuspension of materials from the surface into the air is the primary exposure pathway to nearby human populations. Samples of sediment are collected annually from drainages at and around the LLNL Livermore site after the cessation of spring runoff. Although added as a new sediment sampling location in 1997, ALPO was not sampled in 1997 or 1998 because the location was constantly under water from releases upstream of the Livermore site.

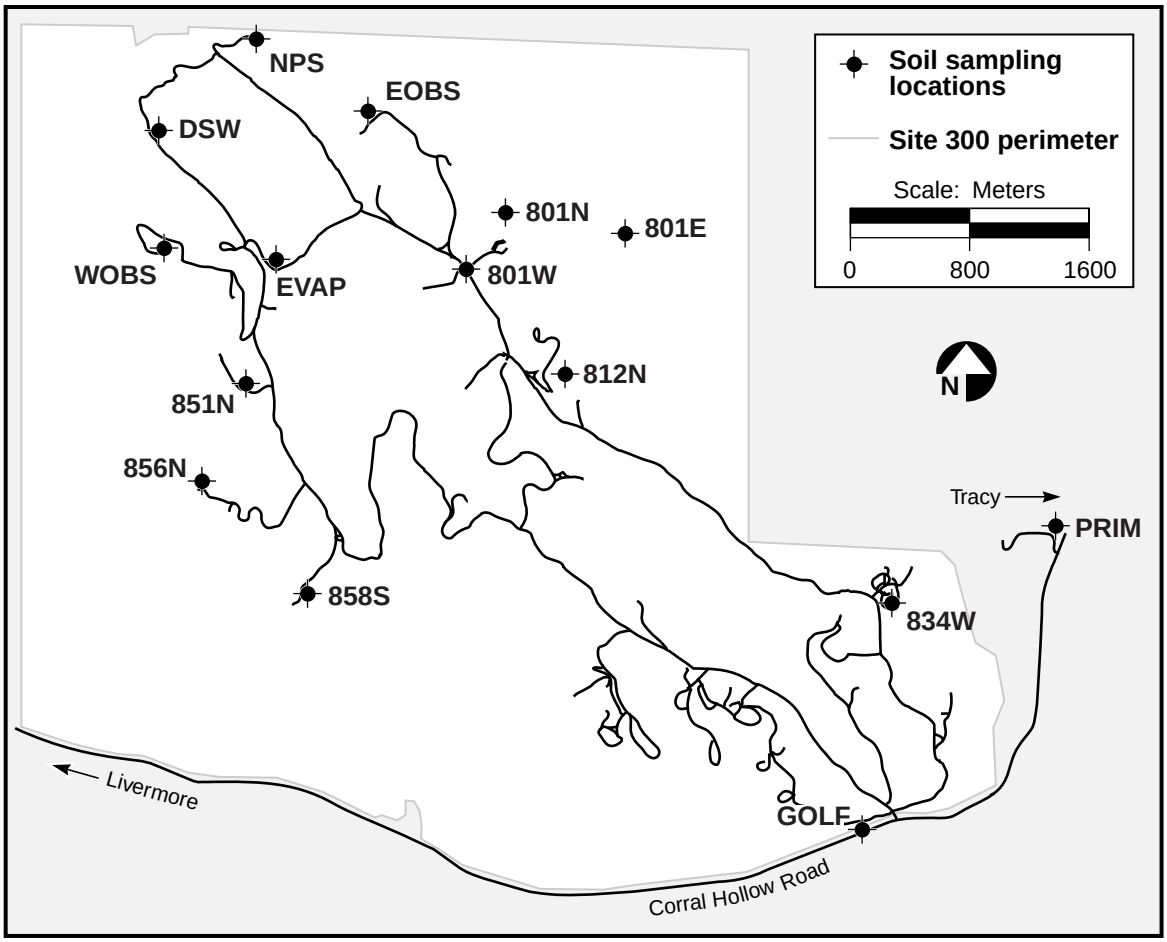

Figure 10-2. Site 300 soil sampling locations, 1998.

For 1998, soil samples in the Livermore Valley were analyzed for alpha- and gamma-emitting radionuclides. Sediment samples collected at the Livermore site were analyzed for alpha- and gamma-emitting radionuclides and tritium. Samples from Site 300 were analyzed for gamma-emitting radionuclides and beryllium. Analysis of Site 300 soil samples for plutonium was discontinued in 1997 because plutonium has not been used at the site, and sample results have continuously been at background levels since sampling was begun in 1972.

Soil and sediment samples are dried, ground, sieved, and homogenized. The samples are analyzed by LLNL's Chemistry and Materials Science Environmental Services (CES) laboratory. The plutonium content of a 100-g sample aliquot is determined by alpha spectroscopy. Other sample aliquots (300 g) are analyzed for more than 150 radionuclides by gamma spectroscopy using a high-purity germanium (HPGe) detector (Hall and Edwards 1994a, b, and c). The 10-g subsamples for beryllium

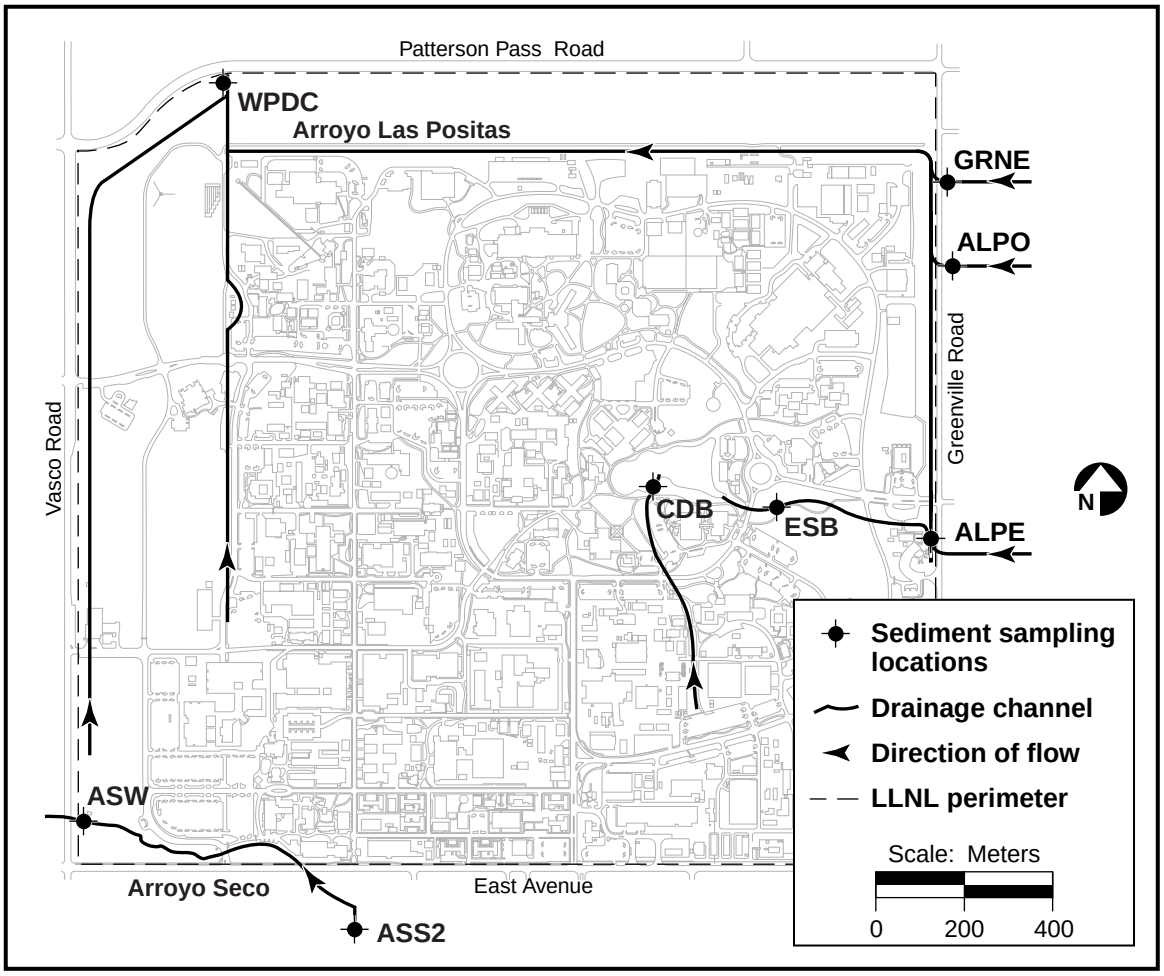

Figure 10-3. Arroyo and drainage basin sediment sampling locations, 1998.

analyses are sent to a contract analytical laboratory and are analyzed by graphite-furnace atomic absorption spectroscopy. For sediment samples collected for tritium analyses, CES uses freeze-drying techniques to recover water from the samples and determines the tritium content of the water by liquid-scintillation counting. Chain-of-custody procedures are followed throughout the sampling, delivery, and analytical processes.

Livermore Valley Results

Table 10-1 presents summary data on the concentrations of $^{239+240}$Pu, ^{238}Pu, ^{137}Cs, ^{40}K, ^{232}Th, ^{235}U, and ^{238}U in surface soils from the Livermore Valley sampling locations. The complete data for 1998 soil and sediment sampling is presented in Table 10-1 of the Data Supplement. The concentrations and distributions of all observed radionuclides in soil

for 1998 are within the ranges reported in previous years and generally reflect worldwide fallout and naturally occurring concentrations. The ratio of ^{235}U to ^{238}U generally reflects the natural ratio of 0.7%; however, there is significant uncertainty in the $^{235}U/^{238}U$ ratio because of the difficulty in measuring small quantities of ^{238}U by gamma spectroscopy.

Plutonium has, in the past, been detected at levels above background at ZON7, the off-site soils sampling location near the LLNL Livermore site and in the prevailing downwind direction. Because of the high level of variability inherent in the measurement of soils, we do not always find plutonium above background levels at this location. In 1998, as in 1991 and 1994 through 1997, $^{239+240}Pu$ was detected at background levels, 173 $\mu Bq/g$ (4.7×10^{-3} pCi/g), at location ZON7. Since 1973, soil samples in this area have generally shown $^{239+240}Pu$ values that are higher than background, and one of the on-site locations upwind of ZON7 did exhibit a $^{239+240}Pu$ value slightly above background, 744 $\mu Bq/g$ (2.0×10^{-2} pCi/g), in 1998. The slightly higher values at and near the Livermore site have been attributed to historic operations, which included the operation of solar evaporators for plutonium-containing liquid waste in the southeast quadrant (Silver et al. 1974). LLNL no longer operates the solar evaporators or engages in any other open-air treatment of plutonium-containing waste. Nonetheless, $^{239+240}Pu$ from historic operations is carried off site by resuspension of soil by wind. Similarly, elevated levels of $^{239+240}Pu$ (resulting from an estimated 1.2×10^{9} Bq [32 mCi] plutonium release to the sanitary sewer in 1967 and earlier releases) were first observed in soils near LWRP during the early 1970s, again were detected at LWRP sampling locations. As in 1990 through 1992 and 1997, ^{241}Am was detected in LWRP samples; it is most likely caused by the natural decay of the trace concentrations of ^{241}Pu that were present in the release.

Historical plots of median $^{239+240}Pu$ concentrations in soil in the Livermore Valley upwind and downwind of the center of the LLNL Livermore site, at Site 300, and at LWRP are shown in **Figure 10-4**. Livermore Valley upwind and Site 300 concentrations have remained relatively constant since monitoring began and generally are indicative of worldwide fallout. Greater variation can be noted in the downwind concentration data, which in 1998 included sampling locations VIS, PATT, NEP, COW, and ZON7, compared to the upwind and historic Site 300 data. The concentrations of plutonium at the downwind locations reflect resuspension of low-level plutonium contamination from soils in the southeast quadrant of the Livermore site. Greater variability in $^{239+240}Pu$ is seen in samples from LWRP. The $^{239+240}Pu$ is likely to be present in discrete particles, so the random presence or absence of the particles will dominate the measured $^{239+240}Pu$ in any given sample.

Table 10-1. Summary of soil and sediment analytical data, 1998.

Analyte and location	Detection frequency[a]	Median	IQR[b]	Maximum
^{238}Pu (μBq/dry g)				
Livermore Valley soils	8/13	2.5	2.4	49.6
LWRP[c] soils	6/6	60	130	381
Livermore site sediments	3/7	3.7	14.8	193
$^{239+240}$Pu (μBq/dry g)				
Livermore Valley soils	13/13	50.3	122	744
LWRP soils	6/6	1070	3030	6070
Livermore site sediments	7/7	25	230	1740
^{137}Cs (10^{-3} mBq/dry g)				
Livermore Valley soils	13/13	1.5	2.1	4.9
LWRP soils	6/6	0.7	1.5	4.7
Livermore site sediments	6/7	0.4	0.3	0.9
Site 300 soils	14/15	2.1	3.2	5.2
^{40}K (Bq/dry g)				
Livermore Valley soils	13/13	0.481	0.118	0.566
LWRP soils	6/6	0.396	0.056	0.448
Livermore site sediments	7/7	0.474	0.039	0.603
Site 300 soils	15/15	0.488	0.063	0.577
^{232}Th (μg/dry g)[d]				
Livermore Valley soils	13/13	7.4	1.9	9.2
LWRP soils	6/6	7.1	0.5	7.9
Livermore site sediments	7/7	4.7	2.1	7.4
Site 300 soils	15/15	9.7	2.2	13.4
^{235}U (μg/dry g)[e]				
Livermore Valley soils	13/13	0.022	0.003	0.025
LWRP soils	6/6	0.019	0.0004	0.023
Livermore site sediments	7/7	0.014	0.010	0.215
Site 300 soils	15/15	0.028	0.008	0.049
^{238}U (μg/dry g)[f]				
Livermore Valley soils	13/13	2.0	0.4	3.3
LWRP soils	5/6	2.3	0.6	3.4
Livermore site sediments	7/7	1.7	0.6	2.3
Site 300 soils	14/15	3.0	2.8	14.9

Table 10-1. Summary of soil and sediment analytical data, 1998 (concluded).

Analyte and location	Detection frequency[a]	Median	IQR[b]	Maximum
^{3}H (Bq/L extracted water)[g]				
Livermore site sediments	6/7	6.5	5.8	15.7
^{241}Am (10^{-3} mBq/dry g)[h]				
LWRP soils	1/6	<2.6	—[i]	—[j]
Be (mg/kg)[k]				
Site 300 soils	15/15	0.9	0.4	2.2

a Detection frequency = the fraction of samples having a measured value above the detection limit.

b IQR = Interquartile range.

c LWRP = Livermore Water Reclamation Plant.

d Thorium-232 activities in Bq/dry g can be determined by dividing the weight in μg/dry g by 247.3, and pCi/dry g can be determined by dividing by 9.15.

e Uranium-235 activities in Bq/dry g can be determined by dividing the weight in μg/dry g by 12.5, and pCi/dry g can be determined by dividing by 0.463.

f Uranium-238 activities in Bq/dry g can be determined by dividing the weight in μg/dry g by 80.3, and pCi/dry g can be determined by dividing by 2.97.

g Only sediment samples are analyzed for tritium.

h Americium-241 is only detected in LWRP soil samples.

i Interquartile range not calculated because of high incidence of reported values below detection limits.

j Maximum value not presented because the only detection is within the range of values reported as below detection limits.

k Only Site 300 samples are analyzed for beryllium.

Table 10-1 presents summary data on radionuclides detected in the sediment samples; a complete presentation of 1998 sediment data is found in Table 10-1 of the Data Supplement. The levels of $^{239+240}$Pu were generally at background concentrations, reflective of worldwide fallout. The moderately higher values at sampling locations CDB and ESB (see **Figure 10-3**) may be attributed to historic activities in the southeast quadrant at LLNL; these locations are both in drainages for that area. Most other radionuclides were detected at levels similar to those reported from 1988 through 1997: ^{137}Cs, a fission product, was found at worldwide background concentrations; and ^{40}K, ^{232}Th, ^{235}U, and ^{238}U—naturally occurring radionuclides—were detected at background concentrations. Tritium concentrations were within the range of previous data. Tritium in sediments was evaluated for differences upwind and downwind of the Livermore site for all data collected from 1988 to 1998. A statistically significant difference was found using the Tukey-Kramer honestly significant difference (HSD) test, with the downwind sediment samples having higher measured concentrations than the upwind sediment samples. Tritium in sediments will continue to be evaluated.

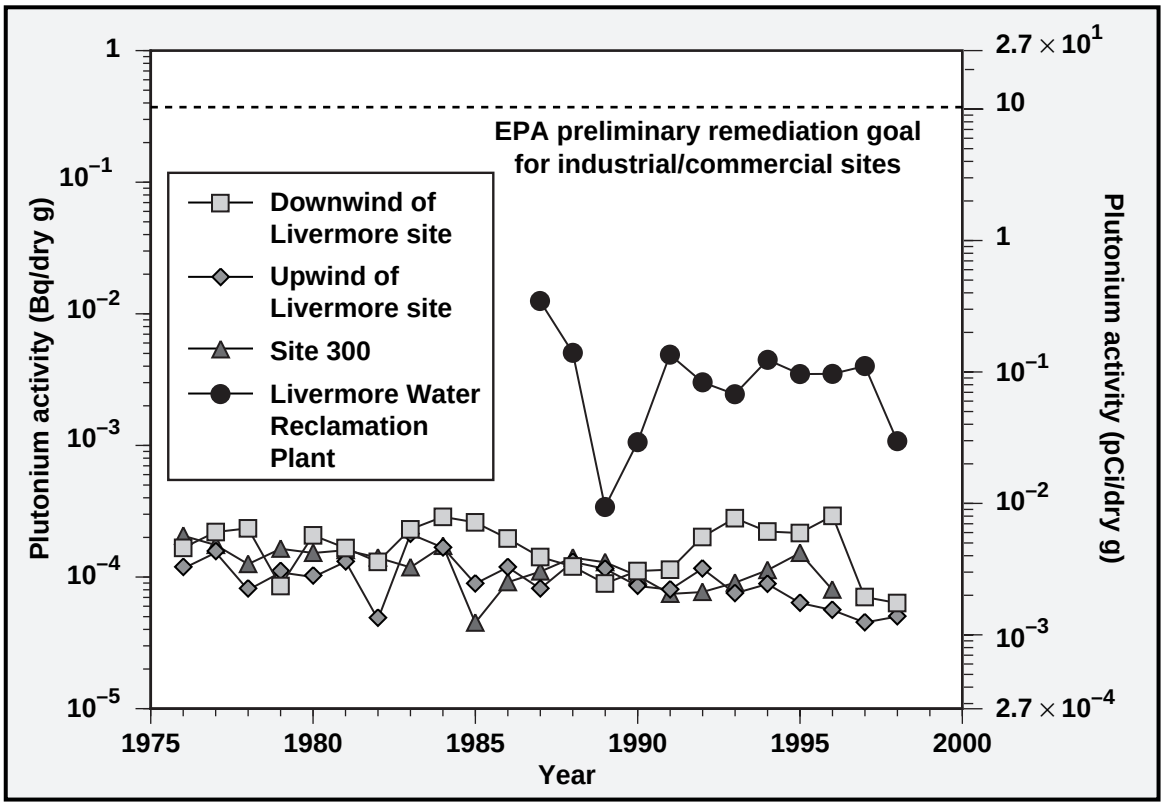

Figure 10-4. Median $^{239+240}$Pu activities in surface soils, 1976 to 1998. Upwind and downwind designations are relative to the center of the Livermore site.

Site 300 Results

Table 10-1 presents summary data on the concentrations of ^{40}K, ^{137}Cs, ^{232}Th, ^{235}U, ^{238}U, and beryllium in soil from the Site 300 sampling locations; a complete presentation of 1998 soils data for Site 300 is found in Table 10-2 of the Data Supplement. The concentrations and distributions of all observed radionuclides in Site 300 soil for 1998 lie within the ranges reported in all years since monitoring began. The ratio of ^{235}U to ^{238}U generally reflects the natural ratio of 0.7%. Historical trends of ^{238}U concentrations from both the Livermore Valley and Site 300 are shown in **Figure 10-5**. Median values have remained relatively constant for both places. The highest values at Site 300 result from the use of depleted uranium in high-explosive tests.

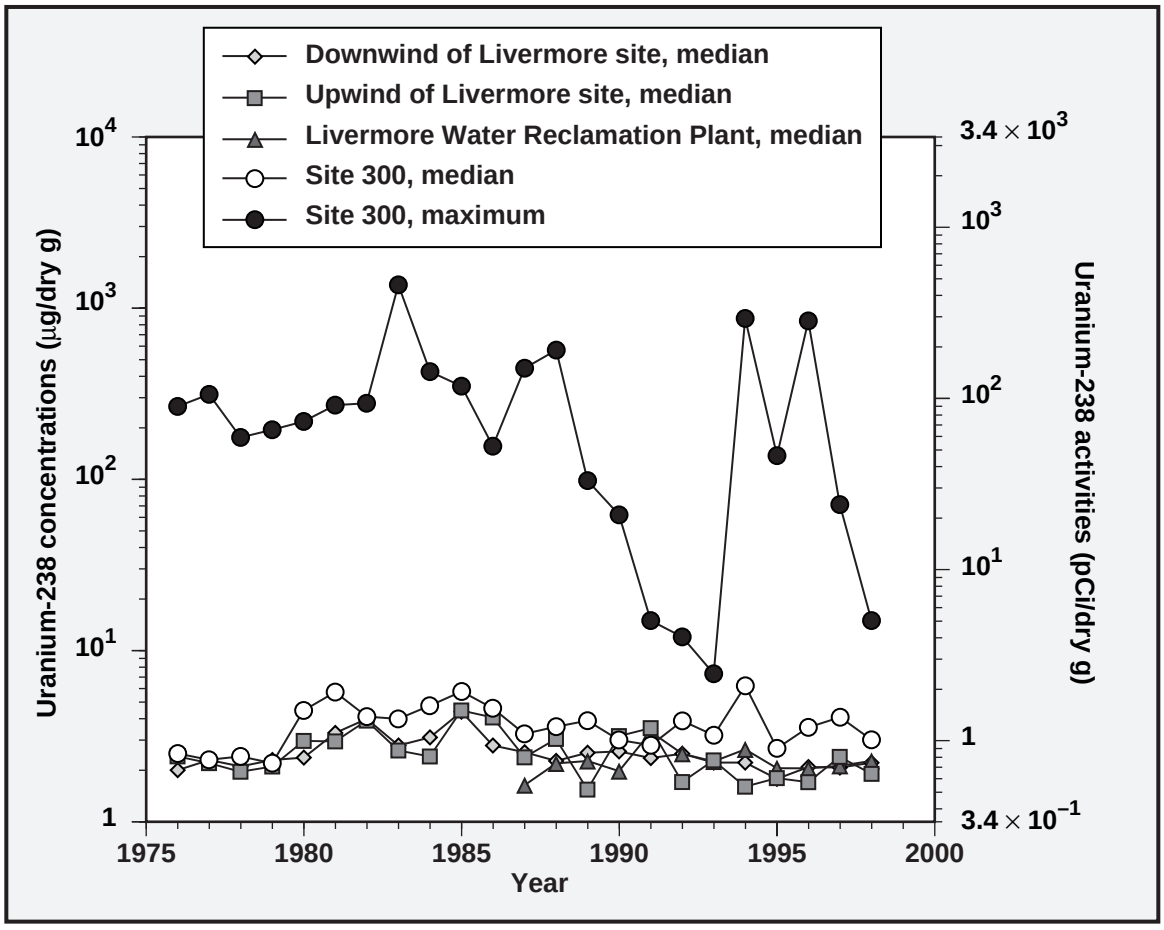

Figure 10-5. Uranium-238 concentrations in surface soils, 1976 to 1998.

Environmental Impact

This section discusses the environmental impacts at the LLNL Livermore site and Site 300 inferred from soil and sediment monitoring.

Livermore Site

Routine soil and sediment sample analyses indicate that the impact of LLNL operations on these media in 1998 has not changed from previous years and remains insignificant. Most analytes of interest or concern were detected at background concentrations, in trace amounts, or could not be measured above detection limits.

The highest value of 6.1 mBq / g (0.16 pCi / g) for $^{239+240}$Pu measured at LWRP during 1998 represents 1.6% of the Environmental Protection Agency (EPA) preliminary remediation goal for commercial or industrial sites of 0.37 Bq / g (10 pCi / g) (U.S. Environmental Protection Agency 1991). Statistical analysis shows there is no general increase or decrease in $^{239+240}$Pu values with time. Moreover, all measured concentrations, regardless of location and year, have been a small fraction of the EPA preliminary remediation goal, which is shown in **Figure 10-4** for comparison. Sampling of soils for radiological materials will continue on an annual basis.

Site 300

The concentrations of radionuclides and beryllium observed in soil samples collected at Site 300 are within the range of previous data and are generally representative of background or naturally occurring levels. The ^{235}U / ^{238}U ratios that are indicative of depleted uranium occur near active firing tables at Buildings 801 and 851, from a small fraction of the operations at the firing table that disperse depleted uranium.

Vadose Zone Soils

Soils in the shallow vadose zone are collected in arroyo channels at the Livermore site as part of the Ground Water Protection Management Program. Infiltration of natural runoff through arroyo channels is a significant source of ground water recharge, accounting for an estimated 42% of resupply for the entire Livermore Valley ground water basin. Soils in the shallow vadose zone are collected and analyzed to provide information about possible constituents that may be dissolved as runoff water infiltrates through the arroyo to the ground water. Sampling locations are generally chosen to coincide with selected stormwater locations (see **Figure 10-3**)

Methods

Vadose zone soil sampling is conducted according to written, standardized procedures. Samples are collected annually from drainages at and around the Livermore site after the cessation of spring runoff. Samples are collected at 30–45 cm for metals analysis and 45–55 cm deep for analysis for selected organic chemicals. Sediment samples were analyzed for organics using EPA Method 8240 for both total and soluble metals using California's Waste Extraction Test. Chain-of-custody procedures are followed throughout the sampling, delivery, and analytical processes.

Analytical results for vadose zone soil samples are compared to soil reuse standards developed by LLNL and the San Francisco Bay Regional Water Quality Control Board (RWQCB) (Folks 1997, Marshack 1991) (see Tables 10-3 to 10-5 in the Data Supplement). Metals background concentrations are based on naturally occurring levels in the soil, considering first the results for total metals and then the soluble metals test. There are no background levels for organic compounds, gross alpha, gross beta, and tritium. Soils containing metals at levels above background or low-levels of organic compounds, gross alpha, gross beta, or tritium still may not adversely affect the ground water. If a metal exceeds both the total and soluble background values, or if there are any detected organic compounds, gross alpha, gross beta, or tritium, the designated level methodology (DLM) is used to determine the soluble levels of contaminants that would not adversely impact ground water beyond its beneficial uses by application of a simple attenuation factor and specific water quality objectives.

The San Francisco Bay RWQCB and LLNL agreed upon an attenuation factor of 100 except for certain metals; the attenuation factor for copper, lead, and zinc is 1000. Any constituents with soluble concentrations above these de minimis levels may adversely impact the ground water beneath.

Vadose Zone Soil Results

In 1998, LLNL sampled sediments in the shallow vadose zones in the arroyos at three influent locations (ASS2, ALPE, and GRNE), the two effluent locations (ASW and WPDC), and two on-site locations (CDB and EDB) in the settling basins upstream of the Drainage Retention Basin (see **Figure 10-3**).

All analytical results for organic compounds were below detection limits. All total metals concentrations were below background (see Tables 10-6 to 10-8 in the Data Supplement). Tritium results were all below de minimis levels, and gross alpha and gross beta analyses were not conducted in 1998 (see Data Supplement Table 10-1).

Environmental Impact

The results of vadose zone soil sampling show that the ground water is not being adversely affected by contaminants carried by infiltration stormwater at the LLNL Livermore site.

Big Trees Park

During the 1993 EPA investigation of plutonium in soils present in the southeast quadrant of the LLNL Livermore site, EPA personnel collected a soil sample at Big Trees Park in Livermore to obtain a background sample. This soil sample showed plutonium at a concentration higher than what is expected from global fallout for this region. The park was resampled by the EPA, LLNL, and the California Department of Health Services (DHS) in 1995. (Over the years, LLNL has frequently investigated the presence of radionuclides in local soils. Several of the studies are listed in **Table 10-2**.)

Table 10-2. Special soil studies.

Year	Subject	Reference
1971–1972	Radionuclides in Livermore Valley soil	Gudiksen et al. 1972; Gudiksen et al. 1973
1973	Radionuclides in San Joaquin Valley soil	Silver et al. 1974
1974	Soil study of southeast quadrant of Livermore site	Silver et al. 1975
1977	Sediments from LLNL to the San Francisco Bay	Silver et al. 1978
1980	Plutonium in soils downwind of the Livermore site	Toy et al. 1981
1990	195 samples taken in southeast quadrant for study	Gallegos et al. 1992
1991	Drainage channels and storm drains studied	Gallegos et al. 1991
1993	EPA studies southeast quadrant	Gallegos et al. 1994
1993	Historic data reviewed	Gallegos 1993
1995	LLNL, EPA, and DHS sample soils at Big Trees Park	MacQueen 1995
1999	Summary of results of 1998 sampling at Big Trees Park	Gallegos et al. 1999

As reported in MacQueen (1995), samples from 13 of the 16 locations sampled during 1995 at the park had plutonium concentrations consistent with background levels found throughout the Bay Area. These levels were 1/600 to 1/10,000 of the EPA's risk-based preliminary remediation goal (PRG) for plutonium for residential areas of 0.09 Bq/g (2.5 pCi/g) (U.S. Environmental Protection Agency 1991). Background values were found in all sandboxes, school grounds, picnic areas, and under the large eucalyptus trees for which the park is named. Samples from two locations had plutonium concentrations slightly above background levels, but still 1% to 2% of the EPA's risk-based preliminary remediation goal for plutonium for residential areas. The four samples collected in 1995 near the 1993 EPA sampling location had results above background, with the highest concentration at this location, 0.038 Bq/g (1.02 pCi/g), being 40% of the PRG.

Based on the 1995 work, both the EPA and the California Department of Health and Human Services (DHS) concurred that there was no regulatory concern from any of the sample results, that there was no significant lifetime cancer risk resulting from the low concentrations of $^{239+240}$Pu in the soil samples, and that there was no unacceptable risk to human health or the environment.

In 1997, the Agency for Toxic Substances Disease Registry (ATSDR), which had contracted with the California DHS, Environmental Health Investigations Branch to conduct a health consultation for plutonium, held a public meeting on the subject of plutonium at Big Trees Park. At this meeting, the regulatory agencies restated that although the levels of plutonium at Big Trees Park were not a health concern, they were interested in knowing how the plutonium got to the park, and that this question warranted further investigation. The report issued by ATSDR on this subject was issued in draft in 1998; the final report was issued in May 1999.

On the basis of the draft report, LLNL volunteered to conduct additional sampling and analysis to investigate how plutonium got to the park and to work with the regulatory agencies to assure public concerns were met. In August and September 1998, more than 300 additional soil samples were collected at Big Trees Park. The sampling strategy was based on choosing sampling locations and analytes (1) to provide data to better determine the vertical and lateral extent of plutonium in soils at Big Trees Park, (2) to provide data at locations and depths that are believed to be unique to each of three plutonium distribution pathways, (3) to provide data at areas of public concern, and (4) to provide additional data for locations previously identified as exhibiting above-background plutonium concentrations in soil.

The results of the 1998 sampling effort have provided much more information about the vertical and lateral extent of plutonium levels in soil at Big Trees Park. The results clearly show no systematic distribution of plutonium at depth. Only four of the 130 samples collected deeper than 10 cm to characterize the vertical extent of contamination had concentrations of $^{239+240}$Pu above background levels determined from historic surveillance sampling. The results for samples collected to evaluate the lateral extent of contamination clearly show an increased level of plutonium along the northern boundary of the park, where the ornamental trees are planted (see **Figure 10-6**).

The results can also be used to draw conclusions about the route of transport of the plutonium to the park. Three routes to the park were investigated: (1) water-borne plutonium-contaminated sediments transported via the Arroyo Seco, which cuts across the southwestern corner of the Livermore site and flows past Big Trees Park on its

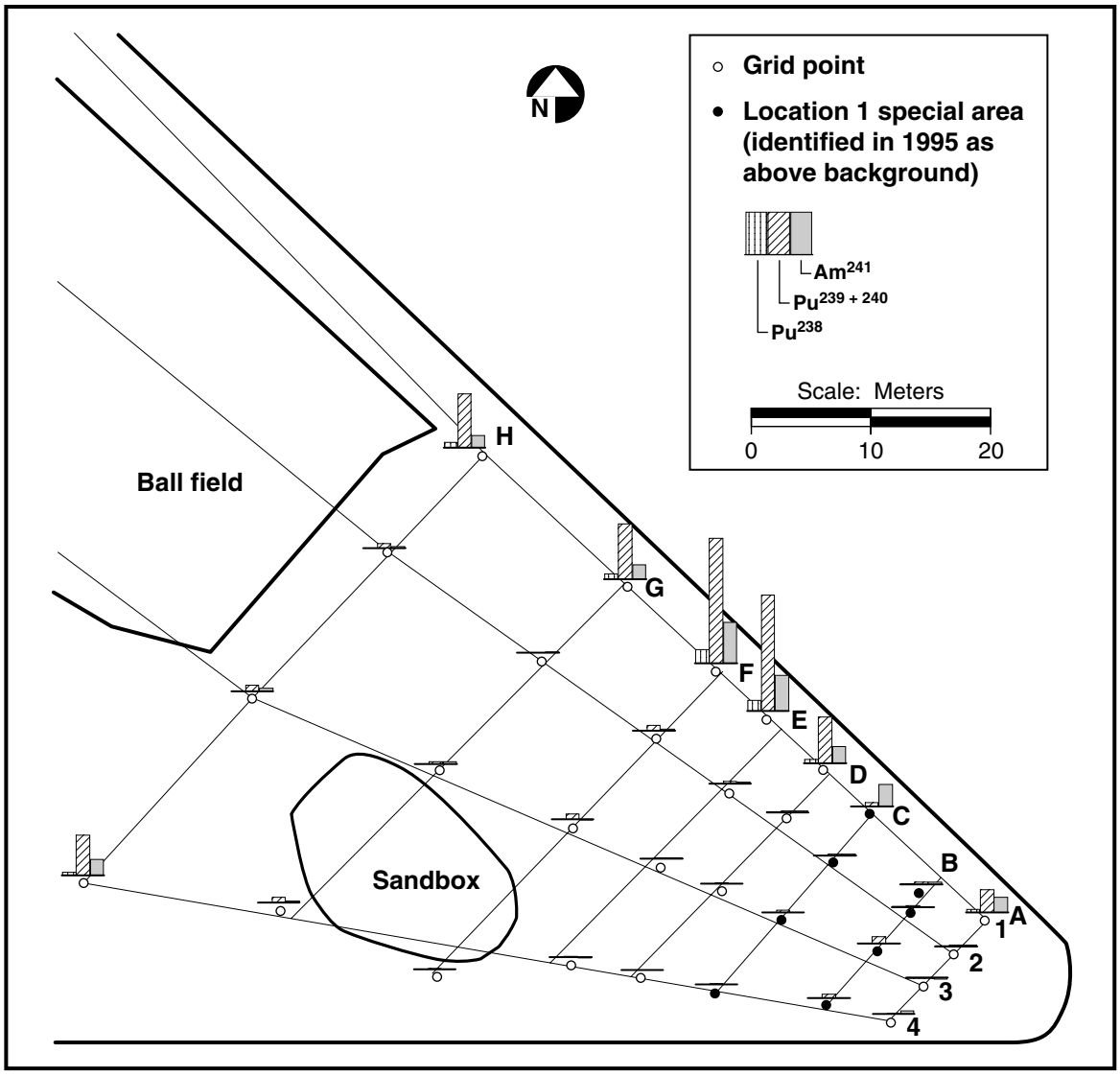

Figure 10-6. Bar graphs of relative radionuclide concentrations at grid locations at Big Trees Park in Livermore. Plutonium results are the averages for the 0–10 cm depth interval, and americium results are averages for the 0–5 cm depth interval. Highest concentrations are shown to lie along the northern park border, near the ornamental trees. (Numbers 1 through 4 identify grid radial lines; letters A through H identify grid perpendiculars.)

northern boundary; (2) plutonium-contaminated sewage sludge used as a soil amendment for planting the ornamental trees along the northern boundary of the Park; and (3) aerial distribution of releases from the Plutonium Facility. The results for the samples collected to investigate the water-borne hypothesis were nearly all below detection limits.

Because the concentrations of $^{239+240}Pu$ were so low in these samples, the water-borne hypothesis is considered to be unlikely. In addition, annual surveillance monitoring of the arroyo shows no residual of past releases nor evidence of recent release.

The sewage sludge hypothesis is based on the fact that sewage sludge was distributed to the public by the LWRP from the early 1960s to the mid-1970s. The probable source of plutonium in the sludge is releases to the LLNL sanitary sewer, with the largest single release occurring in 1967. It is also known that ornamental trees were planted in a row along the northern border of the park, next to the arroyo sometime between 1972 and 1975. Ten trees along the northern boundary of the park were selected for sampling. Paired with each tree location was another location at least 1 meter beyond the irrigation berm that surrounds each tree. The results from these samples clearly show elevated levels of plutonium in samples taken near the trees but only background levels outside the trees. This distribution of plutonium at the park supports the theory that contaminated sewage sludge was used to fertilize trees at the northern border of the park. Additional support for the sewage sludge hypothesis is the similarity of results from inside the tree wells compared to depth averaged values for grid radial 1. (To the extent possible, grid radial 1 and the line of trees were coincident.) These results are graphically displayed in **Figure 10-7**.

Another pathway that has been suggested for transmission of plutonium to Big Trees Park is aerial distribution. The pattern shown in **Figure 10-6** is not consistent with aerial distribution because aerial distribution would show randomly distributed elevated levels of plutonium throughout the park. Additional data available about air dispersion of plutonium also are not consistent with an air route of transport of plutonium to the park. Sampling systems at the Plutonium Facility (Building 332) consistently show no emissions from that building, except in 1980 when a release occurred. (All plutonium-handling operations are triple-high-efficiency particulate air [HEPA] filtered.) Air dispersion modeling of the 1980 release yields unmeasurable levels of plutonium at the park, even assuming the wind was blowing directly from the Plutonium Facility to the park. Similarly, modeling of resuspension of plutonium found on the southeast quadrant of the Livermore site also cannot explain the pattern of plutonium distribution at Big Trees Park. In addition, air surveillance data collected throughout the Livermore Valley do not yield any results that would indicate air deposition is the cause of the plutonium levels measured at the park.

Special sampling at locations at the Arroyo Seco School, which borders the park, including a playing field and an unimproved field that is annually disked for weed abatement, and at the eastern extension of the park yielded concentrations well within the range of background. Special sampling at the locations of the highest concentration found in 1995 generally confirmed above-background concentrations but not at the 1995 levels.

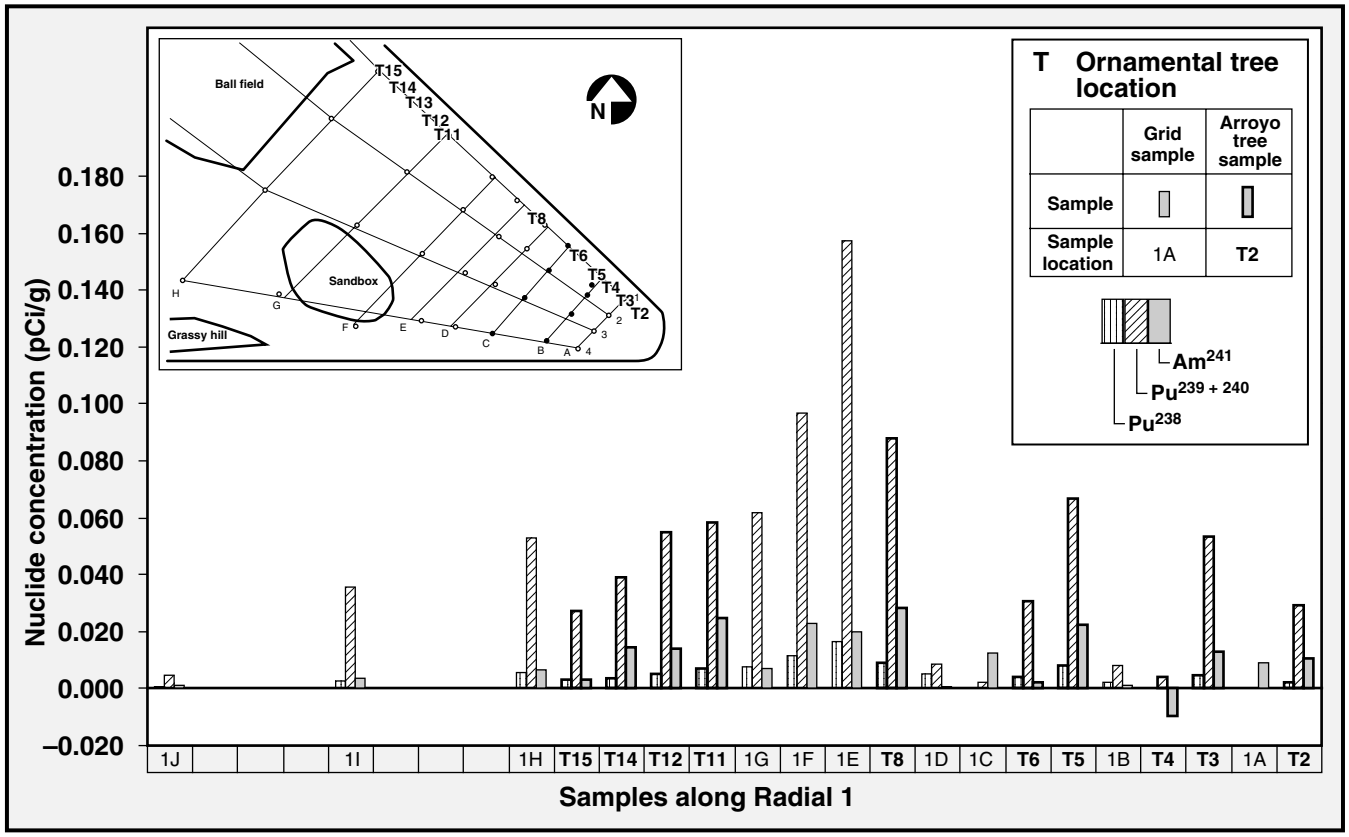

Figure 10-7. Plutonium and americium concentrations measured at grid locations on Radial 1 and in tree wells. Tree samples were taken at 0–45 cm depth intervals, and grid samples were normalized to the same depth interval. Tree locations are outlined with heavy lines for comparison with grid.

Impact

The results of this extensive sampling effort demonstrate again that the plutonium is not present at a level of health concern. All sample results were less than the PRG and were less than values measured as the result of previous sampling efforts at the park. The highest sample concentration from the 1998 sampling effort was 0.029 Bq/g (0.79 pCi/g) $^{239+240}$Pu, well below the residential PRG of 0.093 Bq/g (2.5 pCi/g). Again, the EPA, California DHS, and ATSDR concur that there is no unacceptable risk to human health or the environment from the levels of plutonium at the park.